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OSD CALS Architecture
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UNITED STATES
DEPARTMENT OF DEFENSE
Computer-aided Acquisition &
Logistic Support (CALS)

October 1989

OSD CALS
Architecture Master Plan Study

CONCEPT PAPER

CONFIGURATION MANAGEMENT

Prepared by

U.S. Department of Transportation
Research and Special Programs Administration
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- **Use of Flexible Manufacturing Systems** for local manufacturing will achieve reduced inventories and faster response to supply requirements. The use of this technology demands that data be delivered in digital form and that CM maintains current information on the relationship between engineering and manufacturing data.
- **Growing complexity of weapon systems** in terms of numbers of components and their interrelationships results from the continuing introduction of new technologies into existing weapon systems and other improvements.
- **Increasing use of common parts and assemblies** among weapon systems requires that CM systems are able to track changes in common components across weapon systems.
- **Growth in online access to distributed technical data** demands that a CM system controls the effects of user-initiated changes to data.

All of these changes in weapon systems are aspects of the more fundamental challenge to integrate processes throughout the weapon system life cycle and to integrate such processes among different weapon systems. Integration of WSLC functions is impeded by the current lack of DoD access to contractor data, the divisions between engineering and support functions, and the presence of multiple systems for identifying product data, support data and commodity items. CALS will bridge these gaps in large part through an effective program for the configuration management of technical data.

1.2 The CM Problem

Whether the need is managing a weapon system acquisition or performing a repair, accurate CM data is essential to virtually all WSLC functions. For example, the quality of manufactured components requires that the final product meets well defined DoD specifications. CM data defines the functional and physical characteristics of the manufactured component and in so doing establishes the criteria which guide and test the conformance of a manufactured product to DoD requirements. In the case of a support function like maintenance, it is necessary to know what components are on a particular weapon system and what equipment is required to support the component. CM data provides that critical information.

A major problem confronting the DoD in managing the physical configuration of the weapon system is the rapidly escalating complexity of weapon system components, equipment, software, facilities and technical information. Weapon systems consist of thousands of individual components, each of which may require particular types of support equipment and data to perform required functions. During the course of the weapon system life cycle many of these components and support elements undergo multiple revisions. Because of the increasing frequency of revisions and the fact that the operational life of a weapon system may exceed twenty years, the potential number of combinations of system elements, their versions and their relationships is enormous and rapidly growing, in many cases beyond the management capabilities of current procedures and systems.

For CALS the problem is compounded by the demands of managing digitally stored data. In the current environment, keeping track of the version of a paper document presents the same requirements as configuration management for any other physical component of a weapon system. When that document is digitally encoded in an automated system, however, the re-

quirements change radically. Without proper standards governing how the information is stored and communicated, the multiple formats present in geographically dispersed systems may make it impossible for all users to access needed data. Configuration information will have to be managed across dispersed and varied automated systems. Moreover, CALS systems which automate technical data must be able to interact with other specialized DoD automated systems. Finally, under CALS the frequency of modifications to data items will vastly increase. CALS must then address the special requirements for maintaining current configuration data and controlling changes among an increasingly complex set of interdependent units of technical data. Failure to address these new requirements effectively will make it increasingly difficult for CALS databases to satisfy a fundamental requirement: to maintain and deliver current and consistent technical information.

1.3 A CALS Approach to CM

CALS will make possible a new set of capabilities for data management which will have a substantial impact on WSLC functions. Digitization of technical data, for example, will make it possible and desirable to access subunits of technical documents and to combine pieces of data from many sources in response to a particular user demand for information. CALS will also enable automated update of interdependent technical data items. Change in a single data item would generate a chain of updates for related data items.

In order for these capabilities to be realized and for technical data to remain consistent and up-to-date, CALS will have to take a new approach to configuration management. Features of the CALS approach to CM include

- **Support for linkage among configuration items** – Configuration Management under CALS will require expansion of what is included in configuration data to provide for linking related configuration items.
- **A logically central system for managing technical data** – Configuration Management is a global function which affects every item of technical data within CALS. Coordinating CM functions in the distributed CALS environment will require central administration of standards for data and policies for the execution of CM functions.
- **Stability in standards for configuration data** – While standards for engineering drawings and other technical data will evolve over a long period of time, the earliest implementation of CALS will require standards for identifying versions and status of data items. Stability in CM standards will permit technical data to be accessed and exchanged in spite of changes in other standards and technologies.

1.4 Report Objectives

Support for CM will strongly influence the overall structure of the CALS architecture. It is, therefore, vital that the requirements for CM are identified at an early stage in CALS planning. This paper will provide a high-level analysis of CM requirements for CALS and recommend specific actions that DoD should take in this area.

The present paper has three objectives:

- **To identify CM issues which will affect the development of the CALS architecture**
- **To assess CM requirements for CALS**

- **To recommend steps which DoD should take to address CM requirements**

Corresponding to these objectives are three sections in addition to this introduction. Section 2 examines the nature of CM in the current environment. The purpose is to identify deficiencies of current configuration management systems and issues which will be important to address in the course of CALS planning. Section 3 analyzes the requirements for CALS CM. Section 4 then derives recommendations for DoD actions in response to the requirements for CM described in the previous sections.

The analysis of CM involves examining CALS requirements from three perspectives—the functional view, the data view, and the technology view. These perspectives correspond to aspects of the CALS architecture that must be defined in order to guide the development of actual systems for managing technical data. With respect to CM, the first perspective states what functions must be performed to manage the configuration of weapon systems and associated technical information. The data perspective specifies what information will be required to perform those functions. The technology view defines the character of the automated systems, communications links, and related standards that are required to manage and apply configuration data for CALS.

In the following sections, CM functions, data and technology will be examined in order to identify deficiencies in current approaches to CM. These problems will point to issues concerning CM that the DoD must address in the course of CALS planning and a set of overall requirements that CALS must satisfy in order to perform CM effectively.

SECTION 2. CM WITHIN THE DOD: CURRENT ENVIRONMENT AND ISSUES

Historically, procedures for CM grew up around the need to manage the acquisition process. Both contractors and the Services needed a precise means to define the functional and physical characteristics of the weapon system and its components. The CM process would ensure that contractors delivered products that conformed to specifications. This need for clearly defined information on the content of individual weapon systems was gradually applied to operational functions. Maintenance personnel, for instance needed to know exactly what part belonged where on what system. Configuration management ensures that such information in support of DoD acquisition and operations is current, and that versions of components, equipment, and supporting data correspond correctly.

2.1 CM Functions

The focus of CM is the configuration item (CI). CIs are those components or sets of data whose configuration is managed as a discrete entity by the CM system. According to MIL STD 482A, a CI is "an aggregation of hardware/software, or any discrete portions, which satisfies an end-use function and is designated by the Government for configuration management." In fact, there is a certain amount of ambiguity in how a weapon system is structured in relation to independently managed CIs. As will be mentioned later, CALS may make it possible and desirable to divide CIs into smaller units, especially for technical data.

In defining the state of a weapon system for the DoD, CM systems perform these basic functions—1) documentation, 2) change control, 3) status reporting, and 4) support for reviews and audits.

- **Documentation** of weapon system configuration defines the system's functional characteristics—what the weapon "does", as well as all its physical elements—what the system consists of. A weapon system's physical elements extend beyond components to support equipment, software, technical data and more. The result is called the configuration baseline.
- **Change control** monitors and authorizes changes in a weapon system's configuration baseline. Change control maintains consistency among the weapon system's components and data (configuration items) and also helps enforce DoD standards.
- **Configuration Status Reporting** enables managers to trace changes to the configuration baseline or conduct other activities involving identification, control and audit functions. Typical status reports may include a CI index, revision of a technical order, the status of an ECP, or the status of implementing a physical modification to a component.
- **Reviews/Audit Support** uses configuration information to support the review processes for weapon systems development and modification. Functional configuration and physical configuration audits verify that CIs' specifications and test data are consistent with functional and physical configuration requirements. Audits also check that testing requirements are adequate for verifying the state of "as-built" items. If there are differences, the audit verifies that they are reconciled or that the differences will not affect the item's performance.

During the earlier design and production phases in the WSLC, the emphasis of CM is on control of contractor performance. After weapon system deployment, however, CM data supports such functions as supply, maintenance, and repair. Operations functions require accurate information on the physical configuration of weapon systems, including the technical data that supports those systems. The responsibility for managing configuration information, during this later phase shifts to the DoD.

Documentation, change control, status accounting, and review/audit support carry over into operations, but in somewhat altered form. Modifications during operations, for instance, correspond to design changes in the earlier acquisition phase. Controlling the configuration baseline in relation to a proposed modification is as important as controlling the baseline for a design change during system development.

Implementing the change, however, requires tracking installation of the modification for each instance of the weapon system. This corresponds to auditing the "as-built" product of a contractor for conformance to baseline specifications in the earlier phase. Following deployment, description of the weapon system can be called the "instance" configuration. This description of specific physical elements of each deployed system—along with associated technical data—is essential to many functions supporting the weapon system. Nevertheless, up-to-date information on instance configuration is not universally available.

2.2 Functional Issues and Implications

Automated systems and related policies for managing physical configuration of weapon systems are more widely implemented than those for managing technical data. As CALS provides for digital storage and delivery of technical data, it will be necessary to establish standardized procedures for managing the configuration of technical data in the automated environment. CALS must address a number of key issues related to CM as it develops mechanisms for managing technical data.

- **Current efforts to maintain CM functions following weapon system deployment are inconsistently carried out.**

  During the acquisition process, formal procedures and automated systems commonly support CM functions. After deployment, formal procedures and automated systems in support of CM vary from one weapon system to another. The difficulty in maintaining CM data in relation to operations functions is frequently due to the inaccessibility of contractor CM data, limited use of automated systems in support of CM, and the lack of standards for managing and using configuration data among organizations, the weapon systems, and data management systems.

- **No mechanism currently exists for coordinating configuration of diverse types of technical information.**

  Within CALS, many functions make use of technical data obtained from multiple sources. Modification of a component, for example, may employ R&M information from a maintenance organization as well as engineering drawings from the original design. Information from these multiple sources may be in multiple formats, involving text, graphics, and analytical models. Such combinations of distributed information for a specified function will require identifying and controlling configuration information for each source of data.

2.3 CM Data

CM data defines and controls changes to a baseline that identifies the state of the weapon system and its support at a given point in the system's life cycle. As the weapon system moves from concept to deployment, CM data is produced in the form of functional, allocated, and product baselines.

Functional Baseline

During acquisition, functions to be performed by the weapon system are identified and documented. These specifications define what the contractor must satisfy in terms of performance characteristics of the weapon system and its support elements.

Allocated Baseline

The allocated baseline defines individual CIs and specifications prepared by the contractor that describe what must be delivered in the product. The CI (e.g. a product component, computer program or data set) is normally produced by a single contractor, managed and tested as a unit. One function of CM is to monitor the conformance of CIs as designed and produced according to the allocated baseline.

Product Baseline

The product baseline defines the weapon system in terms its components and the relation of those components to other CIs—e.g., software, support equipment, facilities, and technical data.

One of the challenges of CALS is to address the complexity of configuration data which reflects the complexity of weapon system configuration items and their relationships. What CM data must identify can be pictured in terms of three dimensions (see Figure 1).

Dimension 1 reflects how elements of the weapon system (configuration items) can be divided into product components and support. The support elements necessary to sustain and operate the system include support facilities, tools, supplies, and manpower. The product group includes physical components and software. Technical data is considered part of the support for the weapon system. Figure 1 illustrates the connections between technical information and both physical product components and physical support elements.

Dimension 2 describes the hierarchical decomposition of a weapon system into systems, sub-systems and further subdivisions in accord with the system's breakdown structure. These breakdowns may vary among services and from one system to another. To take one example, the Navy standard configuration item levels are Ship Class, Ship, System/Mission, Sub-System, Equipment, and Component.

Dimension 3 differentiates configuration data according to how data changes during the weapon system's evolution. During design of the system, the weapon system and its components are described in terms of a generic configuration. Such generic configurations vary with respect to version, and versions may change as designs evolve or because of other intentional variations in the baseline configuration.

Following production, configuration data varies according to the "instance" of the weapon system. As already mentioned, instance data describes the different characteristics of each deployed system.

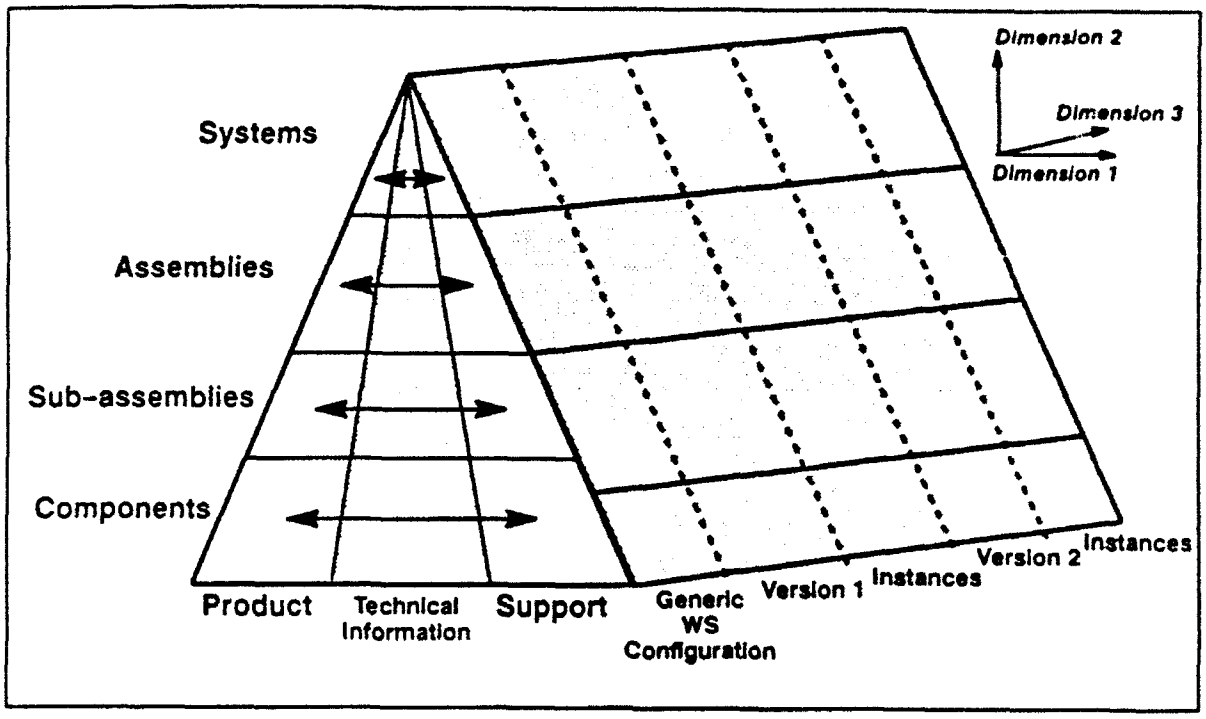

Figure 1. Categories of Configuration Data

Configuration data specifies where the CI stands in relation to this structure—where the item is located in the hierarchy of system components and assemblies, its connection to technical information and support items, as well as version and instance information.

2.4 Data Issues and Implications

Through the introduction of automated systems for technical data, CALS will address several deficiencies in current methods for handling CM data.

- **Current systems cannot provide up-to-date configuration data.**

  The degree of automation in support of CM varies widely among weapon systems. In some cases, identification of components on weapon systems is maintained manually. The complexity of weapon systems makes it difficult, if not impossible, for such systems to maintain up-to-date information on even the physical content of weapon systems.

  This problem is compounded for managing configuration data on technical information such as repair manuals and engineering drawings. Currently, the Services have limited mechanisms for tracking and management of changes in technical information. An engineering drawing of an assembly that is modified at one location may then become inconsistent with a technical order containing an image of the same assembly.

  Reciprocally, changing a technical manual that describes a repair procedure may require corresponding changes in training materials or related engineering drawings. In

the Air Force, for example, two million pages of technical orders are modified annually. Keeping information current in the technical order database is becoming a growing necessity. Currently, delays of many months now accompany such changes. An automated CM system will speed the process.

- **The DoD has limited access to industry-generated configuration data.**
  Currently, lack of automated CM support in the services and lack of standards in data and systems to support access and delivery to the Services inhibits the use of CM systems for logistics and operations functions. Ideally, the DoD should have access to all data required for maintaining configuration in support of acquisition, logistics support and operations. Since configuration data will change during a weapon systems operating life, delivery of configuration data when the system is deployed is insufficient. The Services need to manage changes in configuration in real time. Since contractors are involved in ongoing support and weapon system modification, there must be links between DoD CM systems and contractor CM systems. None of these capabilities now exist.
- **Identification of "instance" configuration is incomplete.**
  Currently, configuration data on individual weapon systems is not universally available. For some older systems, the manual documentation of system components is out-of-date. In such cases, identifying required technical information for such functions as repair and maintenance depends on visual inspection of the system itself.
- **Current support for links among technical data items and between technical data and physical configuration items is inadequate.**
  Defining interfaces among configuration items is a part of current CM responsibilities. Nevertheless, CM systems now provide very limited support for identifying relationships among configuration items involving technical data. The same holds for support of relationships among the physical components of the weapon system.

2.5 CM Technology

Currently many different types of automated and paper-based systems carry out CM functions. The degree of automation varies widely according to system location and the application of the CM data.

Contractor Systems

The complexity of configuration management during acquisition has led to the widespread automation among contractors of major weapon systems. Contractor systems track CIs during the development and production process and deliver CM reports to the DoD.

DoD Systems for Managing Physical Configuration

For many weapon systems, the physical configuration is tracked by DoD automated systems responsible for handling a specific operational function such as repair or maintenance. In other cases, the current configuration is maintained manually by means of a paper document for recording configuration changes.

DoD Systems for Managing Technical Data Configuration

In a few isolated instances, automated systems have been used to manage configuration data for specific categories of technical data, particularly engineering drawings. The most signifi-

cant effort is the Army's Technical Data Configuration Management System, or TD/CMS. This is a relational database which has been prototyped for engineering drawings. It will be implemented on a wider scale in the next year. There is no system, however, that coordinates CM for all types of technical data within any of the Services.

2.6 Technology Issues and Implications

Automated systems for CM have often been developed independently within many different DoD organizations. The lack of coordination poses obstacles for automated support of CM functions.

- **Automation is not uniformly applied in support of CM.**

  Automation for CM is limited to isolated applications managing particular classes of technical information such as software documentation. Multiple systems performing specific functions often use separate sets of configuration data. The result is a decreased reliability of CM data and increased costs for managing the information. More importantly, many functions depend on common access to distributed data, which in turn requires a uniform application of automated support of CM to all relevant sources of information.

- **Multiple, inconsistent standards for automated CM systems impede digital delivery of CM data to DoD organizations.**

  The proliferation of different systems for generating and managing technical data has spawned a corresponding number of mechanisms for controlling configuration. The result is a need for standards to govern how CM data is generated and how it can be transferred from one automated system to another.

SECTION 3. NEW CAPABILITIES AND REQUIREMENTS

By moving from the current paper-intensive environment to one in which technical data is generated, managed, and delivered in digital form, CALS will be able to provide new capabilities that will improve WSLC functions. In this section, we will describe some of these benefits and the requirements that CALS must meet in order to realize the improvements in CM.

3.1 The Functional Perspective

3.1.1 Basic Functional Requirements

At a minimum, CALS must provide the same functions for maintaining configuration of technical data as current policies require for maintaining configuration information on the physical components of a weapon system. The basic requirements for the CM system for technical data are then to document the state of the technical data item, control changes to the data, report on the status of the item, and provide for reviews and audits.

Other functional requirements are specific to CALS. Providing automated support for CM, will require that CALS

- Provide a simple user interface to CM data;
- Establish policies for CM that will give the DoD online access to contractor CM data as well as delivery of contractor data to DoD databases; and
- Maintain continuity for CM functions while new CALS technologies, standards, and procedures are introduced.

3.1.2 New Capabilities

In addition, new configuration management capabilities will permit the growing complexity of technical data to be used in qualitatively different ways than it is now. New capabilities enabled by CALS will include:

- **Using automated systems to identify and track relationships among configuration items, thus enabling more thorough evaluation of change proposals.**

  While current CM procedures require that interfaces between configuration items be identified, such activities are limited by the lag in automated CM support. More sophisticated automation will enable more thorough reviews of potential interactions. Ideally, the CM system will be able to identify, evaluate, and track all relevant interactions among CIs. A proposed modification for a weapon system component, for example, would draw upon automated identification of CI relationships to assess the effects the modification would have on all other related components. Processing such relationships would permit a more rapid and accurate evaluation proposed modifications.

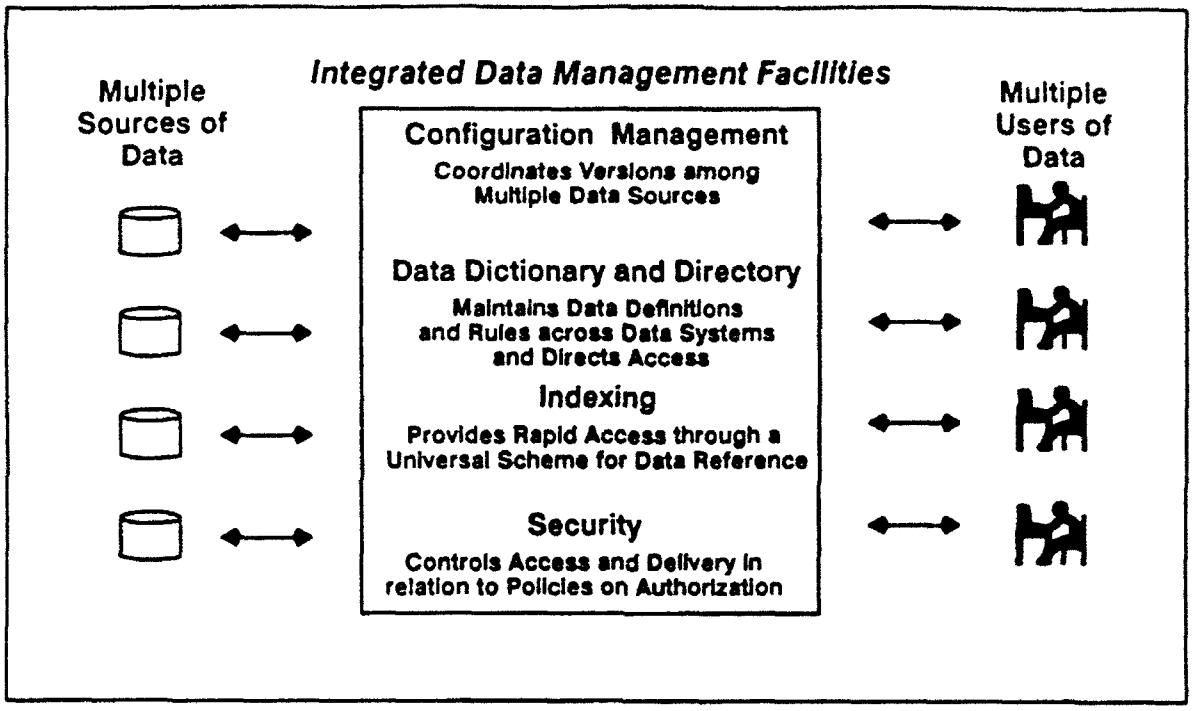

Figure 2. Data Delivery in the Integrated Environment

- **Providing version control for distributed databases that supports automated delivery of technical information from multiple sources.**

  A fundamental task of CALS data management is to access data that resides in multiple locations and in multiple forms (text, graphics, analytical models, etc.) and deliver that information according to the diverse requirements of various users. In combination with other data management functions (see Figure 2), configuration management will ensure that the correct versions of technical data are delivered in a timely fashion in response to the specific data requirements of DoD users.

- **Providing online feedback for reporting errors and proposing changes to technical information or configuration data, and providing a means for tracking the status of proposed changes.**

  Automating CM data will enable users to obtain, verify, or propose changes to configuration data and technical information much more rapidly than they can today. The system will track the status of requested changes to weapon system technical information and perform consistency checks on related data.

- **Enabling automated update of technical data.**

  The ability of the automated CM systems to track potential interactions and dependencies among CIs will make it possible to use automated procedures to update technical data. With this capability, any change in a given configuration item causes the data management system to appropriately modify all related configuration items and keep the relevant configuration baselines up–to–date. In earlier stages of implementing CM within CALS, this process would be partially automated. The CM system would be able to identify range of potential effects of a proposed change to guide assist data managers with the update process.

- **Providing for fine-grained management of technical data configuration items**

  As automated CM systems become more widely implemented, the amount and complexity of data they handle will increase. This increased capacity will allow the data management system to break CIs into subunits, which can be individually manipulated in relation to change control and use in applications. Such fine-grained management of CIs will enable the to respond more accurately to user requirements.

- **Enabling uniform tracking of configuration items by instance**

  Specifying CIs by instance involves identifying all components, technical data, and related support items for a particular weapon system delivered to the base or ship. It will provide information on the current state of individual weapon systems throughout the WSLC. Such identification, for example, will permit personnel to make repairs with full knowledge of what parts and what versions of those parts are on a weapon system. With adequate instance data, the CM system can support automatic fault diagnosis and deliver technical data corresponding to the particular version of the weapon system component needed repair.

3.2 Configuration Data Requirements

Effectively managing configuration data requires that integrity of the configuration baseline is maintained—secure, up-to-date and consistent. The CM process must ensure that the baseline changes only when authorized and that it contains all data necessary to describe the currently approved configuration of the weapon system. The process is made more complex as dependencies among CIs are taken into account. A single change in one CI may generate numerous changes in related components and technical data. This process is reflected in Figure 3.

To summarize the requirements CALS CM must satisfy to enable the DoD to track and identify technical data:

- **All technical data relevant to weapon system design, production, support and operations, whether it forms a whole or part of a configuration item, must be unambiguously identified and referenced.**
- **The data will be linked to appropriate physical configuration items (components, software, support equipment and facilities).**
- **Versions of the technical data and the physical configuration item will be correctly matched.**
- **Dependencies will be identified among data elements and between technical data and physical configuration items.**

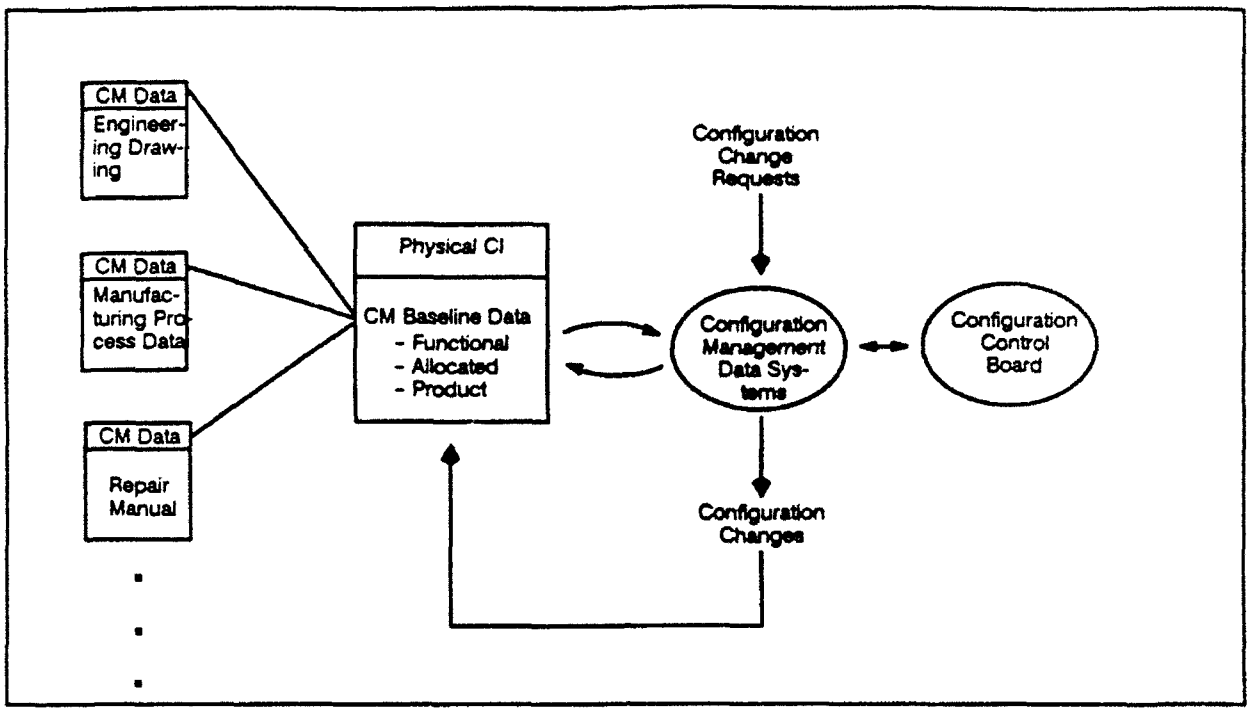

Figure 3. CM Processing of Change Requests

Managing this process across the WSLC will require that the CM system provides other key capabilities:

- **Ability to transfer configuration data, including instance configuration information, from contractors' automated CM systems to systems supporting DoD operations**
- **Provision of automated procedures for change control for physical configuration items, technical information and configuration data**
- **Support for access and grouping of related configuration items through appropriate indexing of CM data**

Linkage of Configuration Items

The primary requirements of maintaining updated and consistent CM data demands that the range of automated CM data be extended beyond the traditional configuration baseline. The improvements in WSLC functions brought about by CALS automation requires that configuration data provide for flexibly linking configuration items. For example, if an engineering drawing is changed to provide for a new maintenance procedure, the CM system will use linkage data to identify which related drawings must be altered and which technical documentation contains references to the changed drawing. The CM system must quickly answer the question: if a given configuration item is changed, what other configuration items will be affected? Linked data will permit the CM system to maintain correct version relationships among related items.

The automated CM system supporting the management of technical data will maintain data related to three types of linkage.

- Links among physical configuration items.

- Links among technical data configuration items and data elements.
- Links between technical data and physical configuration items.

The links will provide critical data on the version of an item, its place in the weapon system hierarchy, and dependencies on other technical data. The prominence of linkage data in support of CM and other functions is one of the most significant features distinguishing the CALS approach from the current mode of configuration management.

The chart below (Figure 4) illustrates how CALS extends the types of data relevant to CM. The nature of CM data for the current environment is represented by quadrant **I.** The partial extension into quadrant **III,** indicates that, at present, instance specifications currently are often incomplete or out-of-date. CALS will extend CM data in two directions, instance specification and linkage data. This results in the types of data identified in quadrants **II, III,** and **IV.**

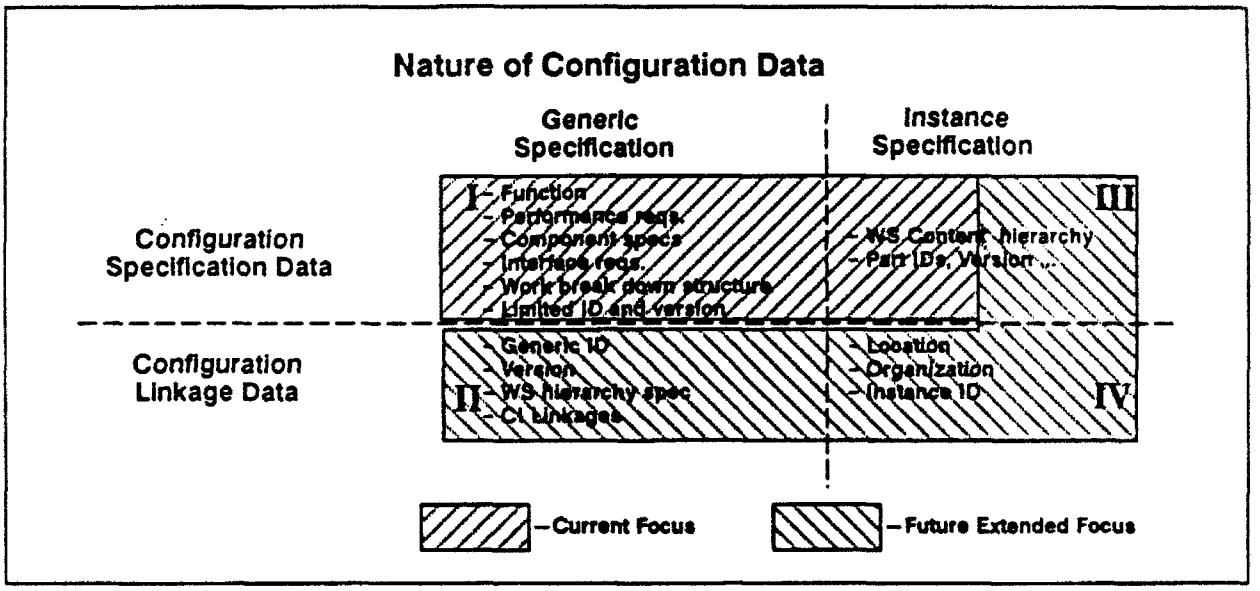

Figure 4

3.3 Technology Requirements

To meet the data management and functional requirements described previously, CALS must establish a logically central system for managing configuration of technical data. While data will continue to be generated and stored at different locations, CM needs to establish communications and data management facilities that will enable the CM database to function as a unit. Central control of CM will ensure consistency of configuration data common to many applications. The actual systems using and modifying the data (when authorized), will be distributed according to the functional demands of DoD and industry organizations. A primary characteristic of centralized control will be the definition and enforcement of standards for generation, storage and transmission of CM data.

Technological support for CM will provide for:

- **Common access to uniformly maintained and standarized configuration data from multiple systems.**

Many automated systems in the DoD make use of configuration data. Systems supporting maintenance, repair, and supply, for example, need current information on weapon system configuration and other forms of technical data. The CM system must provide a means for different automation systems to have standardized access to configuration data controlled by CALS.

- **Development of expert systems and other automated means to obtain appropriate configuration information from contractor databases.**

  The DoD must be able to acquire data generated by contractors during the acquisition process. The ongoing proliferation of data systems and formats will necessitate controls on how data is generated, stored, and obtained from contractors. Early in CALS implementation, data delivery from the contractors and access to contractor data will be achieved through standardized storage and data exchange protocols. Later on, expert systems will extract specific data required for current and anticipated DoD user applications.

- **Development of interfaces between systems managing physical configuration of weapon systems and systems for managing configuration of technical data**

  Currently, automated systems for supporting configuration management of weapon systems components are in more advanced than systems for supporting CM of technical data. As CALS develops digital systems for managing technical data, CM functions will need data on configuration of weapon system components. To meet this need, interfaces must be developed between CALS systems and other automated systems that use and generate CM data.

3.4 CM Functions and the Evolution of CALS

The implementation of CALS will be a process in which contractor and DoD organizations gradually apply new technologies to the management of weapon system technical data. In moving from the current paper intensive environment to integrated management of digital data, the process of CALS evolution will impose many changes on DoD and industry organizations. For the purposes of CALS planning it is useful to simplify this process and describe CALS in terms of four stages: the current paper-based environment, use of automated systems to support digital exchange of data, a shared data environment and an environment supporting integrated applications.

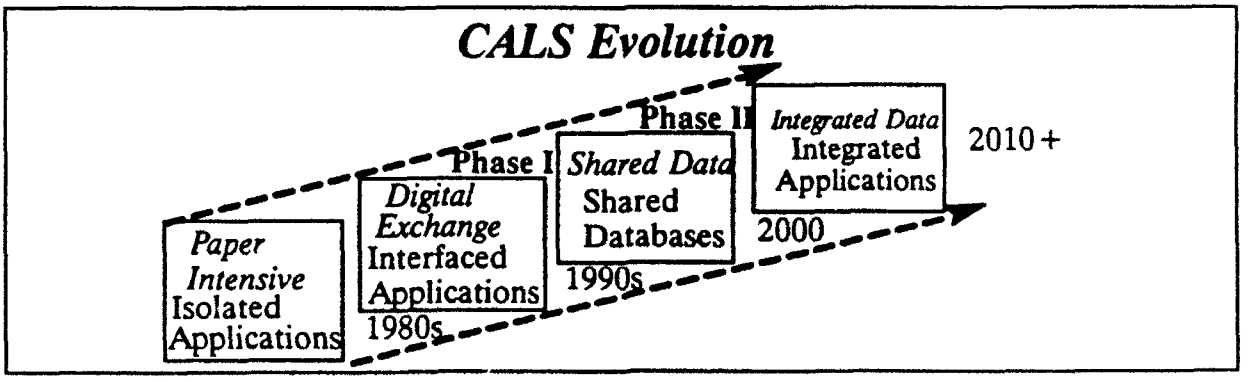

Figure 5 - Evolutionary Stages of CALS

In the current paper intensive environment, automated support for CM is applied on an *ad hoc* basis at contractor and DoD sites. In the case of some deployed weapon systems, configuration data is manually updated. Because of lack of standards among automated systems, and the inability of DoD organizations to receive digital data, information for such functions as status reporting is typically delivered in a paper format.

CALS STAGES	BUSINESS ENVIRONMENT	CONFIG. MGMT. CHARACTERISTICS
PAPER INTENSIVE ENVIRONMENT	• *Non-standardized data* • *Stand alone applications* • *Manual data exchange*	• *Isolated manual and automated CM systems* • *Limited linkage among CIs* • *Course-grained management of CIs*
DIGITAL EXCHANGE ENVIRONMENT	• *Limited standards for data content* • *Interfaced applications* • *Digital media exchange/ limited remote access*	• *Standards for data ID and versioning within weapon systems* • *Standards for data exchange and translation of CM data into standard formats* • *DoD access to industry CM data*
SHARED DATA ENVIRONMENT	• *Standardized tech. data* • *Integrated applications using common data* • *Extensive remote access* • *Dist. heterogeneous processing / logically unified data bases*	• *Standard CM definition and format for most data including commodities* • *Links among related CIs to support automatic update of tech. data* • *Common applications using logistics and operations data*
INTEGRATED DATA ENVIRONMENT	• *Standard data specs* • *Standard applications/ unified WSLC* • *Universal real time access* • *Integrated open system processing*	• *Dependent data linked across all CALS data bases and among all data types* • *Expert support for update and validation* • *Use of expert systems to evaluate and track proposed weapon system changes*

Figure 6 – Evolution of Configuration Management

In the digital exchange environment, DoD standards will govern how digitally stored contractor data is to be delivered to the Services. Reciprocally, digital exchange will enable feedback of operations data into the design process. Applications will exchange information, but will have only limited direct access to remote data. While standards for data storage may vary among contractors and weapon systems, digital exchange does demand that the data be translatable into the DoD standard for exchanged data. Standards for CM, however, must be more restrictive than those for data content. For digital exchange to work successfully, it will be necessary to tag technical data with correct information on version and provide links to related configuration items.

In the third stage of CALS evolution, common CALS databases will support multiple applications in DoD and contractor locations. What data is to be shared is determined by the demands of communities of interest and the requirements of high priority applications. As Concurrent Engineering becomes a more prominent factor in design and modification of weapon systems, CALS will support regular industry access to operations data. Geographically separated managers will be able to evaluate and modify engineering designs and support proposals in concert. Specific applications such as on-demand production of parts in an FMS manufacturing environment will require efficient delivery of diverse types of information. The CM system will help coordinate the supply information, engineering data and manufacturing process data that will be required for a complex application like just-in-time parts production. Shared data among distributed applications will require a higher level of standardization of data content. At this stage, CM data will be further standardized and provide for more complex links among varied categories of distributed data, including technical data related to common parts and commodities.

Finally in the integrated environment, common access to data among multiple users and applications will be extended to all technical data. Rather than provide common access on the basis of specific application requirements, integration will provide transparent access to all data. New applications which may require new combinations of data access and delivery will be more efficiently implemented in this environment. Through extensive use of expert systems, data management functions will adapt the pathways for data access to evolving user requirements. CM will play a crucial role in providing this integrated capability. Expert systems for CM functions will provide automated validation of changes made in technical data. As the universe of interconnected data is extended, this process will become highly complex. The ultimate effect of creating a capability for efficient and complete evaluation of proposed and implemented changes in technical data will be increased flexibility in how data supports DoD functions, and increased responsiveness of the DoD to changing demands on the design, production, and use of weapon systems.

SECTION 4. RECOMMENDATIONS FOR A CALS CM STRATEGY

4.1 Tasks for CALS Planning

The ability to manage change in weapon system design, support and operational procedures is the main function of CM in CALS. Delivering that capability and realizing its benefits will require coordinated changes in how WSLC functions are performed, how data is managed and how technology is used to support data management.

Some tasks and considerations that will affect CALS planning and the development of a CALS architecture are discussed below.

- **CALS must define the scope of CM functions and determine the division of responsibility between DoD and contractor organizations for controlling configuration and maintaining configuration data.**

  An essential issue to be resolved is the range of functions that CM will perform in the CALS environment and further, how those functions will be distributed between DoD and contractor organizations. While much of the CM data for weapon systems is generated by contractors during the acquisition process, the DoD needs to acquire CM data, and control how contractors generate, use, and modify it. What data is acquired, and how DoD controls are exercised are important questions to be decided as CM policies for CALS are formulated.

- **Policies will have to be developed to manage changes in WSLC functions that result from automating CM.**

  New capabilities resulting from CALS implementation will cause substantial changes to WSLC functions. For example, improved access to CM data and new linkages among CIs will reduce time now spent on evaluating and implementing modifications. This will require changes in the way the modification process currently makes use of information and how organizations take advantage of the reduced time-scale of the process.

- **Continuity in carrying out CM functions will have to be maintained while new technologies are introduced for managing technical data**

  Since CALS will be introduced over an extended time period, and since CM functions are essential to maintaining and delivering CALS technical data, the CALS architecture and implementation plan must provide for continuous CM support throughout the process of CALS evolution. CALS must address the issue of how to design standards that can evolve as systems change to meet newly defined requirements.

- **CALS must define new boundaries for CM data.**

  Automation will extend the range of CM data that may be relevant to managing technical information. It will make it possible to manage a larger, more interconnected set of CM data. CALS will also enable DoD to manage more frequent modifications to

technical data. A key issue is determining what CM data will be required to support CALS, including requirements for managing linkages among CIs.

- **Level of depth in identification and increased control of subunits of technical data configuration items will affect system cost and complexity.**

  Digitization of technical data will make it possible to manage subunits of configuration items for updating related data and delivering such information to users or information systems. Increasing depth will increase the cost and complexity of data management systems while providing higher levels of functionality. This trade-off between depth and cost must be addressed in order to define the capabilities of CM within the CALS architecture.

- **Establishing standards for CALS configuration data will require assessing trade-offs among alternative standards and coordinating proposals among competing standards organizations.**

  CM standards will be at the core of CALS standards which permit data from many sources to be stored, maintained and delivered to users. Systems standards must define relationships between DoD automated systems for CM and corresponding contractor systems; relationships between CALS automated systems and systems external to CALS that use and modify configuration data; and a communications infrastructure for distributing CM data. Issues relevant to standards creation which have to be addressed include:

  - Trade-off between timeliness and depth — A higher-level standard can be delivered and implemented more quickly, than a standard that may be wider in scope.
  - Coordination between DoD and standards generating bodies such as NIST, PDES working groups, and industry associations (e.g. EIA G-33 committee on Configuration and Data Management)

- **Integration among CM and the other core data management facilities of indexing, security, and data dictionaries must be carefully defined.**

  There is considerable overlap among the CALS core facilities of CM, indexing, data dictionaries, and security. The CALS architecture will define how these facilities can be integrated.

  CM and indexing serve to identify technical data items in relation to other weapon system elements. CALS needs to establish how indexing facilities will support the needs for linking related configuration items and related subunits of technical data within CIs.

  Business rules for validating data are the province of both CM and data dictionaries. The CALS architecture must define how data dictionary facilities can be used to support CM processes for validating data changes and linking dependent data elements.

  Maintaining the integrity of data is a combined responsibility of CM and security systems. The CALS architecture must take into account how security functions will support CM.

4.2 Developing a Strategy for CM

The CALS architecture will provide for a set of data management capabilities which include the requirements for CM that have been outlined in the previous sections. A detailed definition of that architecture must define the specific mechanisms that CALS will need to manage CM data and support CM functions.

A strategy for CM is a plan for managing the evolution of current CM systems and practices in order to achieve the desired state of future operations that CALS will make possible. Like other aspects of the CALS architecture, the CM strategy must be formulated in light of a detailed understanding of the current state of CM support and the requirements for CM in the future data management environment. While this paper has analyzed issues that will affect the development of a CM policy for CALS, further investigation needs to be carried out on the current state of CM systems, the target state for DoD operations, and the CALS architecture itself.

4.3 Near-term OSD Priorities

The usefulness of existing and newly generated technical information will depend on the completeness, accuracy, and timeliness of the associated CM data. While standards for CALS data classes such as engineering drawings may be changing, CM data must form a stable core for data management. It is essential, therefore, that standards for CM are established as early as possible in the evolution of CALS. The following efforts would help achieve this result:

1) **Identify core requirements for CM functions, data, and technological support that will link DoD and industry databases.**

   That will involve defining an operational target for CM within CALS; identifying databases which are sources of CALS technical information and assessing the configuration data associated with those databases; defining specific areas in which standards for CM will be required; and coordinating DoD and industry approaches to CM.

2) **Prepare a prototype for CALS CM which would show how CM functions can be performed for technical data involving DoD/industry databases.**

   The prototype will validate CM requirements for technical data in terms of support for WSLC functions and technical feasibility. It will evaluate how DoD and industry databases can be linked through a CM facility providing data access and change control. Such a demonstration would be closely tied to prototype tests for indexing, data dictionaries, and security.

4.4 Longer-term OSD Priorities

1) **Develop detailed CM functional and data requirements for CALS.**

   Specific steps will include validating and refining the current understanding of CM requirements, including specialized needs for DoD Components; assessing the current baseline for CM systems within the DoD and the defense industry; identifying the content of CM data in relation to CALS functional requirements; and assessing the implications of alternative implementation strategies for CALS CM.

2) **Develop CM standards**

The definition of standards for CALS in general and CM in particular will be an extended evolutionary process. Initial steps for defining CM standards include:

- Constructing a set of robust core standards that will enable data access and interchange between DoD and industry systems;
- Developing testing procedures for evaluating conformance to CALS CM standards and for testing compatibility of CALS CM standards with other CALS standards and requirements; and
- Coordinating CALS CM standards with industrial users of CALS data and with other standards generating organizations.

3) **Integrate CM strategy with other CALS data management facilities**

An effective mechanism for CM is necessary but not sufficient for the success of CALS as a data management system. CM functions depend heavily on other core CALS facilities, namely, data dictionaries, indexing and security. The strategy for CM in CALS, therefore, therefore, has to be coordinated with plans for the other data management functions.